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Design and development of a table-mounted manual drilling machine for the rural purpose

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Abstract
This paper presents a simple and flexible table mounted manual drilling machine designed and developed for rural applications to drill metallic and non-hardened material manually. The drilling machine is one of the essential devices with its applications where a circular cross-section hole is required. However, the manually operated drilling machine was developed for small drilling operations. It eradicated the major challenge of the inability to access electricity in most hamlets and villages across the country where solid materials such as wood and metalwork were engaged daily. The lack of power has deteriorated the economy and reduced some essential services to minimum benefit in those vulnerable areas. The high cost of equipment, especially the highly technological machines, has prompted the implementation of the simple but technically based manual drilling machine (MDM). The use of the manual approach in producing holes in solid materials is of more significant advantage in the rural communities where their sources of income and purchasing power are deficient.

Keywords: manual drilling machine, drilling operation, purchasing power, solid material

1. Introduction

n engineering technology and workshop practice, there are various means of creating a hole in solid materials, including gas cutting, perforation, casting, and punching. Nevertheless, there are none of these methods that the surface, center to center distances, and the diameter of holes have been proved accurate as in the drilling process. Also, the drilling operation is versatile in most wood and metal industries [1]. The drilling of the hole is achievable using a machine with a cutting edge tool also known as the drill bit, which imposes a relevant force on the workpiece mounted on the worktable to produce a hole or extend the size of the hole on different solid materials such as woods and metals [2, 3]. There are different purposes for drilling holes in materials. These include the accommodation of shafts, rivets, bolt, and screw. The machine coverts, back, and forward motion to rotary motion and it can be operated using hand while some powered by compressed air and electricity. The drilling operation carried out using a lathe machine, where the drill bit fixed into the tailstock of the lathe machine [4]. Furthermore, various operations could be performed on drilling machines, apart from drilling, such as tapping, boring, reaming, tapping, countersinking, spot face, grinding, counterboring. These operations were possible based on different tools attached to the chuck of the drilling machine [5]. In 1882 Tomlinson described a drilling machine made by Whitworth and company as one of the complete tools of the kind ever constructed. Since then, the general form and development of the drilling machine had not thoroughly changed between 1850 and 1900. The definite improvements made arose mainly from the possibility of using a higher speed of rotation and feed following the introduction of high-quality steel and improved twist drills [6, 7]. Although there are several kinds of drilling machines with different configurations and applications. Furthermore, there are some researches carried out towards the operational processes of the drilling machine. Raj et al. [8] proposed how to curb the injury and promote safety in the use of vertical drilling machine. The Hazard Identification Risk Assessment and Variable Frequency Drive (VFD) could correct the damages caused by the drilling machine, which was incorporated into the vertical drilling machine to forestall the hand injury that is often associated with the drilling machine. More so, to enhance energy reduction during operation and provide safety of the equipment. The VFD would enable the small and large scale industries to attain negligible damages within their operational environment. Amin et al. [9] made a study on an automated drilling machine that has two different electric motors, the main motor used in regulating various speeds based on the hardness of the workpiece. The auxiliary motor is employed to control the depth of cut based on the time of operation. The reversed speed used in withdrawing the drill bit from the workpiece, and the system shut down automatically aftermath of the usage. Wani et al. [10] performed an analysis in the production of vibration during machine processes, including drilling machines. To predict a phenomenon of chatter, the vibration of a drilling machine is fundamental. The result of the analysis enhances the determination of the amplitude of vibration generated concerning spindle speed and size of the drill. Transverse and longitudinal vibration caused a shatter phenomenon and length of the blind hole, respectively. The torsional vibration caused the removal of the workpiece from the material. Kumar and Sekhar [11] did an elaborate study that defined details of the upright drilling machine, designed to work on a medium-sized workpiece. The machine configuration is very similar to a sensitive drilling machine, but this is heavier and larger than a sensitive drilling machine and supplied with the power feed arrangement. There are two main classes of upright drilling machine, and these are the box column section and round column section. Box column upright drilling machine has the square table fitted on the slides at the front side of the machine column. The heavy box column improves machine strength and rigidity [12]. The table is raised or lowered by an elevating screw that gives additional support to the table. These features enable the machine to operate with heavier workpieces with holes more than 50 mm in diameter can be drilled by it. The round column upright drilling machine consists of a round column with its base resting on the floor. The table and the arm have three adjustments for accessing the workpiece under the spindle. The arm and table could move up and down on the column and clamp at a particular position [13]. However, the development of a table-mounted manual drilling machine became imperative in a situation where there is no access to electricity and the inability to possess such expensive drilling machines. Thus, this machine purposely designed for the less privileged community where livelihood threatened. The simplicity of operation and application of this machine will certainly increase the economic power of such localities.

2. Materials and Methods

The choice of material selection in fabricating the table-mounted manual drilling machine cannot be overemphasized because it has to be stable and rigid [14, 15]. Different factors were considered to ascertain the choice of materials for each component. These factors including machine strength, rigidity, durability, service maintenance, tough, strong, excellent resistance to wear, and having the ability not to be twisted, withstand distortion, suspend to bending without deformation, and other rheological problems that the machine will encounter during operation. The material used in the construction of the components was alloy steels, mild steel, high-speed steel, and high tensile steel, which satisfied to have excellent properties. Steels are solid material with improved hardness, especially at high temperatures, to increase the tensile strength and resistance to fatigue and wear [16, 17].

The manual drilling machine is a piece of mechanical equipment used to produce a hole in different materials such as wood and metal. The MDM consists of a column on which other components are attached directly fixed to a worktable. The machine is flexible and compact. It has a wheel that can be turned by hand to cause the spindle on which the chuck was attached to move downward. The device was designed as a replica of radial type, which sorely depends on electricity [18]. The type of drill to be fixed into the chuck depends on the diameter of the hole required, and the cutting speed depends on how fast the machine wheel can be revolved. The feeding system is controlled by turning a small wheel fixed directly on the spindle top of either clock wisely for feeding the tool or anticlockwise to withdraw the tool from the workpiece. The size of the workpiece is no issue with the drilling machine as the integral component's position can be adjusted on the column of the drilling machine, as shown in figure 1.

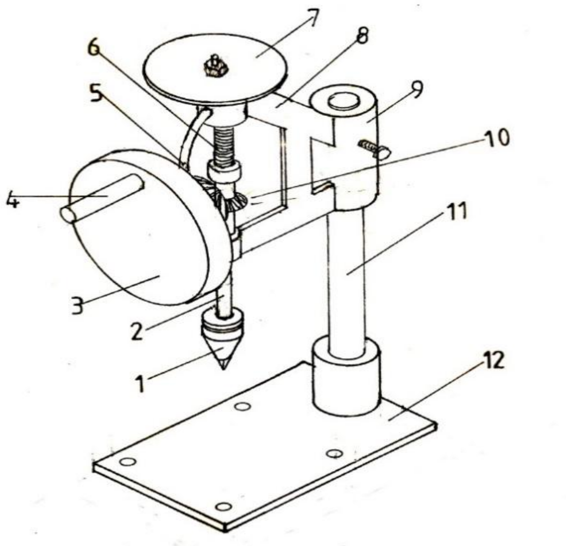

Figure 1: Developed Manual Drilling Machine

The list of the materials used for the construction of the table-mounted manual drilling machine is shown in Table 1.

Table 1: Components used for the developed MDM

S/N	DESCRIPTION
1	Chuck
2	Spindle
3	Flywheel
4	Handle
5	Bracing rod
6	Lead screw
7	Depth adjustment wheel
8	Holding arm
9	Height adjustment boss
10	Pinion
11	Column
12	Working table

2.1 Operating procedures

The manual drilling machine was positioned on a sturdy table and secured with bolts and nuts through the hole provided on the worktable. The device components were adjusted along the column to suit the type of workpiece to be operated. Unscrew the chuck and fit the appropriate twist drill of parallel shark to the drill chuck and tightened it securely. Centre punch the center of the workpiece to be drilled, then turn the depth adjustment adjusting wheel with the left hand so that the drill will have contact with the workpiece that has been secured on the vice. Employ the right hand to turn the handwheel to supply driving motion and continue to turn the handwheel, also turn the depth wheel slowly with the left hand until the hole is drilled. Turn the depth wheel anticlockwise to withdraw the cutting tool from the workpiece.

2.2 Cutting speed for drilling

The table 1 shows a concise report of the optimum cutting speed obtained for various material while testing the machine with 8 mm twist drilling bit.

Table 1 [19]

	Material (m/min)	H.S.S Drill (m/min)	C.S Drill
1.	Mild steel	24 – 45	9 -17
2.	Aluminum	60 – 90	24 – 45
3.	Soft cast iron	30 – 45	12 - 23
4.	Medium cast iron	21 – 30	8- 15
5.	Brass	60 – 90	24 -45
6.	Stainless steel	18 – 21	7.5 – 10.5

3. Result analysis

There is a need to evaluate the parameters used in the design and construction of a table-mounted manual drilling machine. The equation (1) to (20) expressed the design formulation and the configuration of the manual drilling machine.

Pitch circle of the bevel gear

$$P = \frac{2\pi r}{N} \quad \text{(m)} \qquad [20] \tag{1}$$

Where, P is the circular pitch in the plane of rotation, r is the pitch radius and N is the number of teeth in gear.

For this work, the velocity ratio of the bevel gear's pinion is selected to be 1.2 to ensure a higher mechanical advantage to the increase the torque. The number of teeth in the bevel gear was chosen to be 20 for an optimum diameter of 150 mm [21].

Spindle speed

The spindle diameter for the drilling machine sorely depends on the limiting speeds. Also, limit speed depends on the machine size, and this is expressed in equation (2) to (5) for a given cutting speed [19, 22, 23]

$$N = 318\left[\frac{V}{D}\right] \quad \text{(rpm)} \tag{2}$$

But N is greater when $N_g = 318\left[\frac{V_{max}}{D_{max}}\right]$ (3)

N is the least when

$$N_I = 318\left[\frac{V_{min}}{D_{max}}\right] \tag{4}$$

Hence, the range of limit speeds is given by

$$R_N = N_g / N_I = \left[\frac{V_{max}}{D_{min}}\right]\left[\frac{D_{max}}{V_{min}}\right] = R_V R_D \tag{5}$$

Where, R_N is the range spindle speed, R_V is the velocity range and R_D is the diameter range, V is the cutting speed, D is the diameter of the workpiece, N_g and N_I represent taylorized spindle speed, V_{min} and V_{max} refer to a taylorized speed range.

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Feed per minute

The feed per drill bit revolution is the distance the bit advances in the time when the spindle turn through one complete revolution, and the feed per minute is the distance the drill bit advances in one minute. It is expressed in mm/minute.

The formula relates the feed per drill bit revolution and the feed per minute

$$Sm = n \ x \ Srev \quad \text{(m/min) [19]} \tag{6}$$

Where, n is the spindle in rpm, Sm is the feed per minute, Srev is the feed per drill bit revolution.

But for one revolution of the spindle, the bit advances for 3 mm, average values for manual operation is 20 rpm. Therefore, the screw feed in one minute is

$n \ x \ Srev$ = 20 x 3 = 60 mm

Hence, for continuous drilling on non-hardened materials, the screw can feed through a depth of 60 mm.

Range of diameter for the spindle [19, 22]

$$R_v R_D = \frac{N_g}{N_l}$$

(7) $R_D = \dfrac{N_g}{N_l R_v}$

(8)

$$R_v = \frac{V_{max}}{V_{min}} \tag{9}$$

$$R_D = \frac{N_g V_{max}}{N_g V_{max}} \tag{10}$$

$$V = \frac{2\pi r N}{60} \tag{11}$$

$$R_D = \frac{2\pi r}{2\pi r} \tag{12}$$

Therefore, R_D = 1 inch = 25.14 mm = 25 mm

Range of diameter of the spindle is 25 mm, thus, 25 mm spindle was selected for the drilling machine.

The Column

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The column should be absolutely straight so that the load it carries will be uniformly distributed. A column with a factor of safety is given as (13) to (16) [19]

$$P^2 = \left[\delta ypA + \left(1 + ac/i2\right)P\right] p/Fa + \delta ypAPe/\left(Fs\right)^2 = 0 \quad (13)$$

Where, δyp is the yield point stress for the material, A is the cross-section area, C is the distance from neutral axis to the edge of cross section, a is the initial crookedness.

$$i = \sqrt{\frac{I}{A}} \quad (14)$$

i is the radius of gyration, and I is the second moment of inertia. As for other machine elements, a factor of safety must be used in column design. Since the stress is not proportional to the load, the factor of safety (Fs) is applied to the load rather than to the stress.

Then, Pyd is the load on the column that causes the maximum stress to be equal to the yield point value δyp.

If the working load P is equal to $P = \frac{Pyd}{Fs}$

(15) $P^2 yp - \left[\delta ypA + \left(1 + \ ac/i2\right)\ P_e\right]\ Pyd + \delta ydAP_e = 0$

(16)

Working load of the column

The load capacity of the column can be determined using (17) to (20) [24]

$$A = \frac{\pi d^2}{4} \quad (\mathrm{m}^2) \quad (17)$$

Moment of inertia = $\frac{\pi d^2}{64}$ (m^4) (18)

Radius of gyration = $i^2 = \frac{I}{A} = \frac{d^2}{16}$ (m) (19)

Euler load that is the critical buckling load

$$P_c = \frac{\pi^2 EI}{L^2} \quad (\mathrm{N}) \quad (20)$$

Where, E is the young's modulus of elasticity, I is the moment of inertia, L connotes length, P_c is the critical buckling load, A is the cross-sectional area, I is the radius of gyration.

The machine handle

By human economics, the average radius that can conveniently be circumvented by the human hand is 100 mm. [25] Therefore, the length of the handles with reference to its protrusion from the heed stock of the machine was selected to be 100 mm.

Flywheel requirements

The shafts in many types of machinery are suspended to torque loading that differs throughout the work cycle. During the work cycle that needs a high torque, energy from the flywheel aid in the manual drilling process [21]. The driving speed in the manual operation of the drilling machine is low, and any effects from torsional vibration are negligible.

4. Conclusion

The developed manual drilling machine is an improved design of breast type of manual drilling machine because a newbie cannot find the use of breast type very convenient in terms of operation. The cutting motion is provided mainly by turning the handwheel, which in turn tolerates the spindle on which the chuck holding the drill bit is fixed via spindle attached to the bevel gear. The speed of cut depends on how fast the operator can turn the handle while the cutting pressure is applied by turning a small wheel provided directly on top of the spindle. Each rotation of the handwheel produces a resultant triple rotation of the spindle, and this enables to improve the mechanical advantage of the machine. However, further study could be carried out to improve the mechanical advantage and enhance the spindle's torque.

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References

[1] Singh A.K. and Moona N. (2016). Design of a Universal Micro-Radial Drilling Machine. International Journal of Science Technology and Engineering, 2, (9), 154-163.
[2] Kakade, N.U., Bhake, P., Dandekar S., Kolte, R. and Selokar, S. (2017). Fabrication of combined drilling and tapping machine. International Research Journal of Engineering and Technology, 4 (3), 305-307.
[3] Shete, Y. S., Bhosale, A.D., Shinde, S.S. (2018). Fabrication of Universal Drilling Machine. International Research Journal of Engineering and Technology, 5, 4, 1066-1070.
[4] Varne, M.N., Jagushte, G .S., Desai, D.D., Dhotre, V.A. and Mane, S.A. (2018). Design and Fabrication of 360 Flexible Drilling Machine. International Journal for Research in Engineering Application and Management, Special Issue-CTRD, 58-60.
[5] Singh, R. (2006). Introduction to Basic Manufacturing Processes and Workshop Technology (1st Ed.), New Age International (P) Limited Publishers.
[6] Moor, W.D. (1977). Ingenuity sparks drilling history. Oil and Gas Journal, YIII, 75, 159-177.
[7] Kopey, B. (2007). Development of drilling technics from Ancient Ages to Modern Times. 12th IFToMM World Congress, Besangon, 18-21 June, pg 1-4.
[8] Raj, P.J.I., Uthayakumar, M., Sivaprakash, K. (2014). Enhancing Safety in Vertical Drilling Machine. International Journal of Innovation Research in Science, Engineering and Technology, 3 (3) 1064-1067.

[9] Amin, R., Bhowmik, H., Mainuddin, Md., Hossain, S. (2016). Development of a PLC controlled Drilling machine. International Journal of Electronics and Data Communication 3 (5) 148-153.
[10] Wani, A.S., Sagavkar, G.S., Bhate, V.K. (2013). Vibration analysis of drilling operation. International Journal of Student Research in Technology and Management, 1 (2), 163-175.
[11] Kumar, J.S.S. and Sekhar, S.R.S. (2015). An Experiment Study on the Influence Cutting Parameters on Thrust Force" While Drilling on Different Materials. International Journal and Magazine of Engineering Technology, Management and Research, 2 (1) 327-336.
[12] Gupta, H.N., Gupta, R.C. and Mittal, A. (2009). Manufacturing Processes, (2nd Ed.), New Age International (P) Limited Publishers.
[13] Prakash, R.S., Singh, R.D., Singh, B., Prakash, S.A. and Koshy, V. (2018). Design and Fabrication of Multi Axis Drilling Machine, International Journal of Innovative Research in Technology, 4, (11), 702-706.
[14] Banjo, S.O. Bolaji, B.O., Ajayi, O.O., Olufemi, B.P., Osagie, I. and Onokwai, A.O. (2019). Performance enhancement using appropriate mass charge of R600a in a developed domestic refrigerator, IOP Conf. Ser.: Earth and Environmental Science, 331 (1), 1-8.
[15] Banjo, S.O. Bolaji, B.O., I. Osagie, O.S.I. Fayomi, O.B. Fakehinde, P.S. Olayiwola, S.O. Oyedepo, N.E. Udoye (2019). Experimental Analysis of the performance characteristics of an eco-friendly HC600a as a retrofitting refrigerant in a thermal system, Journal of Physics: Conf. Ser. 1378 (4), 1-8.
[16] Singh, U.K. and Dwived, M. (2009). Manufacturing Processes, (2nd Ed.), New Age International (P) Limited Publishers, Daryaganj New Delhi.
[17] Babalola, P.O., Omada, J.E., Kilanko, O., Banjo, S.O., Ozuor, O. (2019). Performance Evaluation of a centrifugal Pump with different Impeller Materials, Journal of Physics, 1378, 1-13.
[18] Hodder and Stoughton (1977). Basic Mechanical Engineering, (1st Ed.) printed in Great Britain by Westminster press group.
[19] Hajra Choudhury S.K. Hajra Choudhury A.K. (1985). Elements of workshop technology, (10th Ed), Media Promoters.
[20] Kiran, R. P. (2015). Workshop Technology, (1st Ed) Vikas Publishing House Pvt Ltd.
[21] Parashar, B.S.N and Mittal, S.K. (2011). Elements of Manufacturing Processes, 10th edition, PHI Learning Private Limited.
[22] Kdenigsberger, F. and Tobias, S.A. (1973). Machine Tools Design and Research Proceeding of the Fourteen International Conference. The Macmillan Press Limited, London, pg.125-132.
[23] Ito, Y. and Matsumura, T. (2017). Theory and Practice in Machining System, Springer International Publishing Switzerland, 71-93.
[24] Kashyap, S.K., Kumar, S., Mallick, M., Singh, R.P., Verma, M. (2018). A comparative study between experimental and theoretical buckling load for hollow steel column. International Journal of Engineering, Science and Technology, 10 (3), 27-33.
[25] Wang, C. and Cai, D. (2017). Hand tool handle design based on handle measurements. MATEC Web Conferences, 119, 1-5.